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EVALUATION OF THE SELF-BORING PRESSUREMETER IN SANDS

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(U) CENTRO DI RICERCA IDRAULICA E STRUTTURALE MILAN

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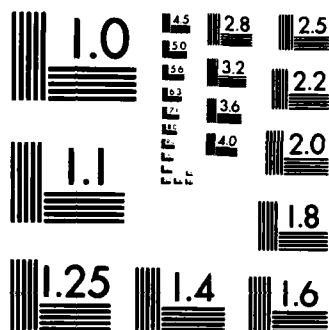
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MICROCOPY RESOLUTION TEST CHART  
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Research Project:

"Evaluation of the Self-Boring Pressuremeter in Sands"

②

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SECOND INTERIM REPORT

(Jan.1985 through May 1985)

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# 1. Present Research Status

This report describes the work performed under the writers supervision during the period of time from January to May 1985:

- a. Eleven SBPT's in Ticino sand (TS) whose results together with those of the first test run on Hokksund sand (HS) are summarized on Table 1. All these tests have been performed using the ideal installation procedure consisting of the following steps:
  - the SBP is placed in the calibration chamber (CC);
  - the specimen is constructed by means of pluvial deposition;
  - the specimens are then stressed under 1-D conditions according to the desired stress history;
  - the pressuremeter test is performed with three unload-reload loops during the expansion phase and one reload-unload loop during the unloading phase.
- b. It has been discovered during the 1-D stressing that the three Camkometer strain arms are subjected to a pronounced mechanical compliance which is responsible, according to the writers opinion, for the following highly undesirable phenomena:
  - the observed lift-off pressure ( $p_o$ ) does not correspond to the applied horizontal boundary stress  $\sigma_o$ : The difference ( $p_o - \sigma_{ho}$ ) increases with an increase of relative density ( $D_R$ ) and with the magnitude of the stress applied to the specimen; see Figs. 1 to 3.
  - The lift-off of the three strain arms does not occur simultaneously.

In view of these compliance problems, a number of simple checks on the Camkometer strain arms have been performed. These results have been summarized in Figs. 4 and 5. They indicate that all the previously described discrepancies observed between  $p_o$  and  $\sigma_{ho}$  in field measurements probably could be attributed to the above examined mechanical compliance problems. (Ghienna et al. (1981), Dalton and Hawkins (1982), Benoit (1983)).

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- c. It was decided to expand the present research programme with a number of flat dilatometer tests [Marchetti (1980)] performed in the CC. The aim was to investigate the reliability of this device to deliver information about the existing in situ lateral stress  $\sigma_{ho}$ . The results of these tests are summarized on Table 2. Fig. 6 shows the comparison between  $K_o$  yielded by the DMT, evaluated according to Schmertmann (1983) procedure, and those resulting from the stress applied on the specimen boundaries. These tests have been performed simulating field conditions; the dilatometer has been inserted into the CC specimen after 1-D stressing and then the DM expansion has taken place.
- d. A series of shear tests on both TS and HS have been performed using the Bishop type ring shear apparatus with the aim of assessing the "constant volume" angle of shearing resistance  $\phi'_{cv}$  of the test sands. The results obtained up to now yielded:

$$TS : \quad 33^\circ \leq \phi'_{cv} \leq 34^\circ$$

$$HS \quad 33^\circ \leq \phi \leq 35^\circ$$

## 2. Research Plans

The plans for further research activity are summarized as follows:

- a. Modifications to the existing strain arms will be made in order to eliminate or at least to reduce drastically their mechanical compliance. The modifications will consist mainly in :
- modifying the existing pivot by inserting into it a miniature roller bearing;
  - making new strain arms of stainless steel in order to obtain much more rigid "beam" elements;
  - changing the arms' support in order to eliminate their torsional and flexural deformation under applied external pressure.

- b. Repetition of the tests on which a large difference between  $p_o$  and  $\sigma_{ho}$  has been observed using the modified probe.
- c. Execution of the additional DMT's for investigating the influence of the CC size and boundary effects on the tests results.
- d. Conversion of the self boring device to use compressed air for inserting the Camkometer probe into the CC specimens.
- e. Analysis of the previously available SBPT's in relation to their possible use in practice.
- f. Triaxial and direct shear tests on pluvially deposited specimens of the test sands used, in order to improve their geotechnical characterization.

Table 1  
SBPT's Results

| Test<br>No. | Sand<br>- | $\gamma_d$<br>t/m <sup>3</sup> | $D_R$<br>% | $\sigma'_v$<br>kPa | $K_o$<br>- | OCR<br>- | $p_o^*$<br>kPa | $G_{ur}^{**}$<br>MPa |
|-------------|-----------|--------------------------------|------------|--------------------|------------|----------|----------------|----------------------|
| 201         | HS        | 1.638                          | 67.0       | 112.8              | 0.662      | 2.8      | 76.2           | 47.7                 |
| 207         | TS        | 1.563                          | 43.9       | 109.9              | 0.586      | 3.3      | 65.1           | 44.0                 |
| 208         | TS        | 1.510                          | 43.2       | 112.8              | 0.400      | 1        | 28.1           | 25.2                 |
| 209         | TS        | 1.528                          | 49.2       | 116.7              | 0.441      | 1        | 46.1           | 34.5                 |
| 210         | TS        | 1.541                          | 53.3       | 511.1              | 0.479      | 1        | 81.2           | 75.8                 |
| 211         | TS        | 1.586                          | 67.4       | 512.1              | 0.473      | 1        | 58.1           | 72.5                 |
| 212         | TS        | 1.577                          | 64.6       | 110.8              | 0.747      | 2.9      | 104.4          | 48.0                 |
| 213         | TS        | 1.523                          | 47.5       | 112.8              | 0.740      | 2.8      | 120.4          | 48.0                 |
| 214         | TS        | 1.507                          | 42.4       | 112.4              | 0.476      | 1        | 49.3           | 32.3                 |
| 215         | TS        | 1.672                          | 92.3       | 514.6              | 0.439      | 1        | 254.6          | 93.8                 |
| 216         | TS        | 1.519                          | 46.3       | 60.9               | 0.927      | 7.7      | 73.4           | 41.0                 |
| 218         | TS        | 1.579                          | 65.3       | 71.5               | 0.990      | 7.7      | 80.3           | 45.9                 |

\* Lift-off pressure as read, in order to obtain the applied boundary lateral stress  $\sigma_{ho}$ , multiply  $\sigma'_v$  times  $K_o$

\*\* First unload-reload cycle

Table 2  
DMT'S Results

| Test No. | Sand - | $\gamma_d$<br>t/m <sup>3</sup> | $\sigma'_v$<br>kg/cm <sup>2</sup> | $K_o$<br>- | OCR<br>- | $p_o$<br>kg/cm <sup>2</sup> | $p_1$<br>kg/cm <sup>2</sup> | $K_D$<br>- | BC<br>- |
|----------|--------|--------------------------------|-----------------------------------|------------|----------|-----------------------------|-----------------------------|------------|---------|
| 97       | TS     | 1.628                          | 1.16                              | 0.445      | 1        | 3.95                        | 12.33                       | 3.405      | B-1     |
| 98       | TS     | 1.669                          | 1.14                              | 0.448      | 1        | 6.52                        | 18.44                       | 5.719      | B-1     |
| 99       | TS     | 1.676                          | 1.13                              | 0.758      | 2.8      | 10.75                       | 25.13                       | 9.513      | B-1     |
| 100      | TS     | 1.628                          | 1.15                              | 0.762      | 2.8      | 6.78                        | 16.97                       | 5.896      | B-1     |
| 101      | TS     | 1.626                          | 1.12                              | 0.585      | 1.5      | 5.03                        | 13.90                       | 4.491      | B-1     |
| 102      | TS     | 1.500                          | 1.11                              | 0.529      | 1.0      | 4.07                        | 11.96                       | 3.667      | B-1     |
| 103      | TS     | 1.534                          | 1.12                              | 0.586      | 1.5      | 3.55                        | 10.35                       | 3.170      | B-1     |
| 104      | TS     | 1.532                          | 1.14                              | 0.780      | 2.8      | 4.21                        | 12.18                       | 3.693      | B-1     |
| 105      | TS     | 1.539                          | 3.20                              | 0.490      | 1        | 8.39                        | 20.20                       | 2.622      | B-1     |
| 106      | TS     | 1.535                          | 1.14                              | 0.470      | 1        | 4.53                        | 13.25                       | 3.974      | B-3     |
| 107      | TS     | 1.537                          | 1.13                              | 0.780      | 2.8      | 5.77                        | 15.20                       | 5.106      | B-4     |
| 108      | TS     | 1.535                          | 1.13                              | 0.790      | 2.8      | 5.68                        | 15.27                       | 5.027      | B-3     |
| 109      | TS     | 1.626                          | 1.15                              | 0.440      | 1        | 4.65                        | 13.10                       | 4.04       | B-3     |
| 110      | TS     | 1.629                          | 1.14                              | 0.755      | 2.8      | 6.87                        | 17.59                       | 6.02       | B-3     |
| 111      | TS     | 1.680                          | 1.14                              | 0.794      | 2.8      | 12.20                       | 28.81                       | 10.70      | B-4     |
| 191      | HS     | 1.687                          | 1.17                              | 0.473      | 1        | 2.65                        | 7.80                        | 2.27       | B-3     |
| 195      | HS     | 1.663                          | 1.20                              | 0.436      | 1        | 6.56                        | 22.70                       | 5.47       | B-3     |
| 197      | HS     | 1.660                          | 0.89                              | 0.910      | 7.4      | 7.15                        | 22.30                       | 8.03       | B-4     |
| 198      | HS     | 1.658                          | 0.65                              | 0.719      | 3.0      | 4.80                        | 16.70                       | 7.39       | B-3     |
| 199      | HS     | 1.655                          | 0.64                              | 0.460      | 1        | 3.50                        | 11.80                       | 5.47       | B-1     |
| 200      | HS     | 1.655                          | 0.64                              | 0.690      | 3.0      | 5.70                        | 18.00                       | 8.91       | B-1     |
| 202      | HS     | 1.655                          | 0.65                              | 0.877      | 7.4      | 4.70                        | 16.70                       | 7.23       | B-1     |
| 203      | HS     | 1.655                          | 0.66                              | 0.450      | 1        | 3.90                        | 13.40                       | 5.91       | B-1     |
| 204      | HS     | 1.581                          | 1.16                              | 0.440      | 1        | 2.30                        | 9.70                        | 1.98       | B-1     |
| 205      | HS     | 1.598                          | 1.13                              | 0.850      | 8.3      | 6.80                        | 21.10                       | 6.02       | B-1     |
| 206      | HS     | 1.597                          | 1.13                              | 0.660      | 3.30     | 3.40                        | 12.70                       | 3.01       | B-1     |

Notes:

BOUNDARY CONDITIONS

B-1: CONSTANT STRESS

B-3:  $\sigma'_v$  CONSTANT;  $\epsilon_h = 0$

B-4:  $\sigma'_h$  CONSTANT;  $\epsilon_v = 0$

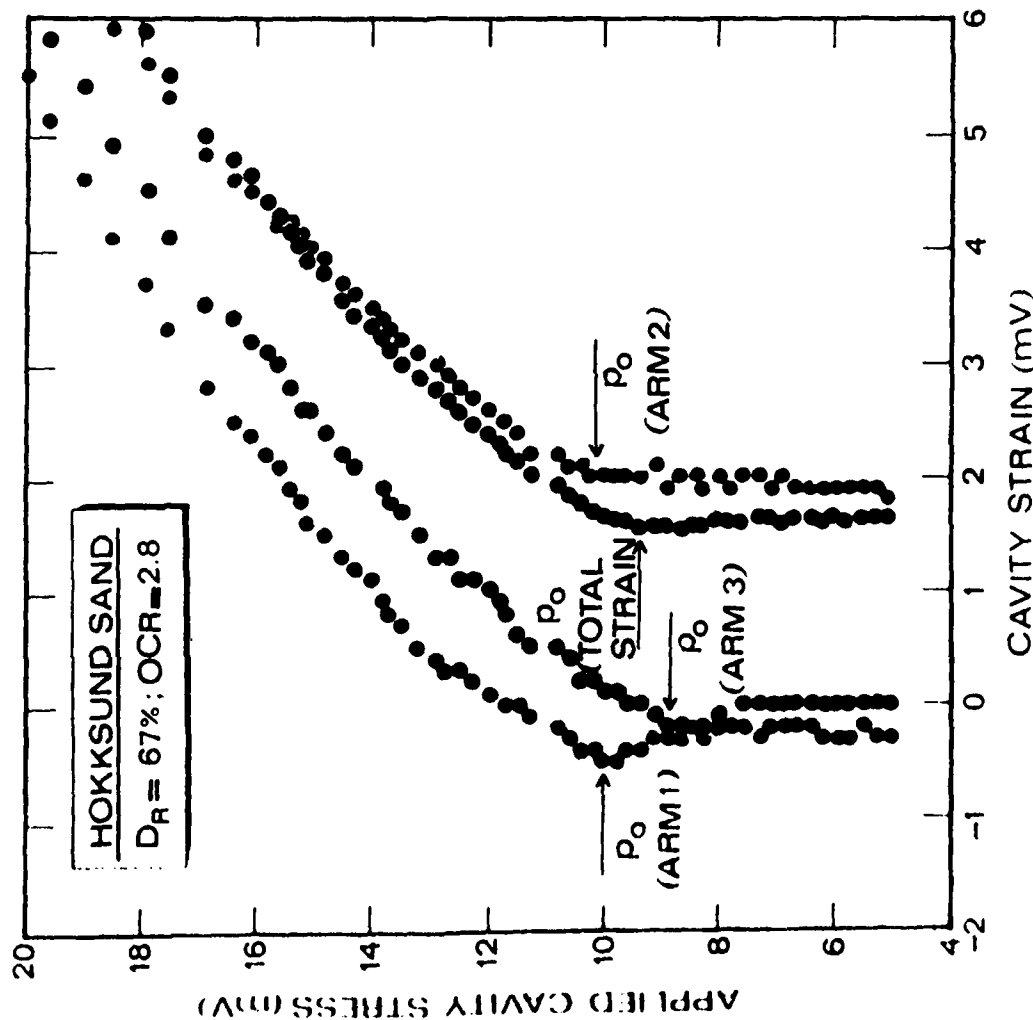
TICINO SAND

$\gamma_{max} = 1.701 \text{ t/m}^3$ ;  $\gamma_{min} = 1.391 \text{ t/m}^3$

Fig. 1

# SBPT IN CALIBRATION CHAMBER -- LIFT-OFF PRESSURE STRAIN ARMS WITH

## LIMITED MECHANICAL COMPLIANCE



STRAIN OF "LIFT-OFF"  $p_o$  (kPa)

|       | 76.2 | 82.2 | 84.2 | 71.2 |
|-------|------|------|------|------|
| TOTAL |      |      |      |      |
| ARM 1 |      |      |      |      |
| ARM 2 |      |      |      |      |
| ARM 3 |      |      |      |      |

APPLIED LATERAL  
 BOUNDARY STRESS  
 $\sigma_h = 74.7 \text{ kPa}$

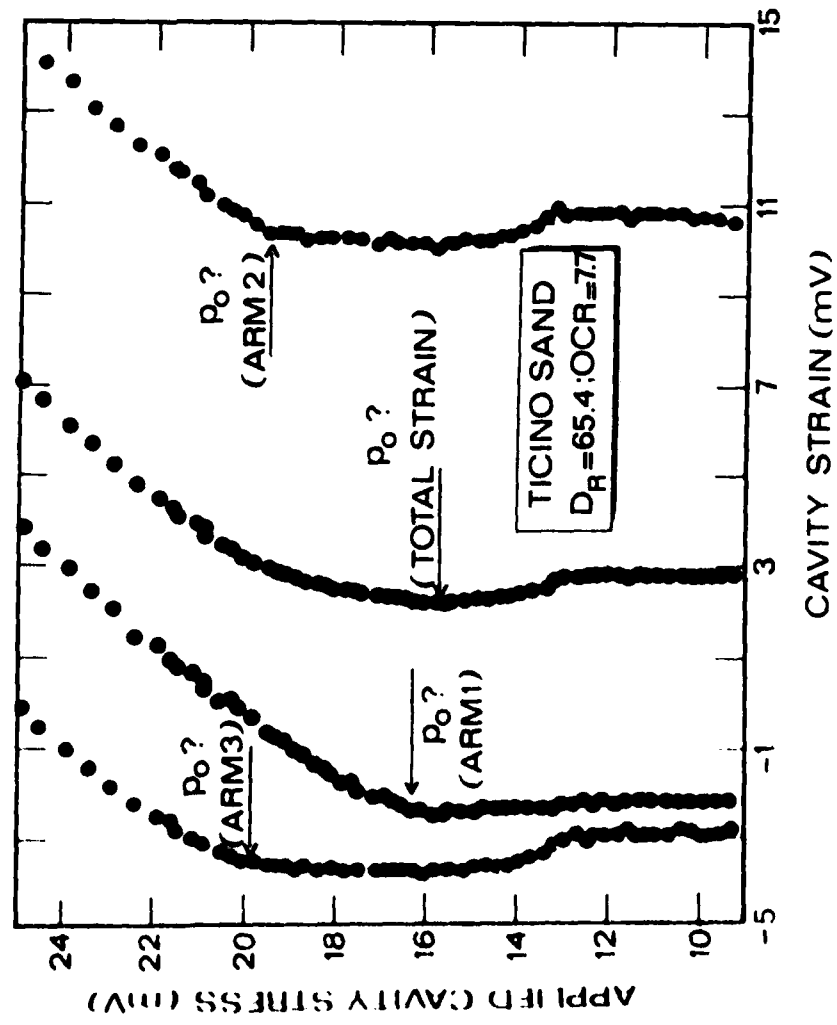
TOTAL STRAIN :  $1 \text{ mV} = 9.5 \cdot 10^{-3}$

SINGLE ARM :  $1 \text{ mV} = 2.8 \cdot 10^{-2}$

CAVITY STRESS :  $1 \text{ mV} = 10.02 \text{ kPa}$

Fig. 3

# SBPT IN CALIBRATION CHAMBER - LIFT-OFF PRESSURE STRAINS WITH A PRONOUNCED MECHANICAL COMPLIANCE



| STRAIN OF "LIFT OFF" $p_o$ (kPa) | APPLIED LATERAL<br>BOUNDARY STRESS |  |
|----------------------------------|------------------------------------|--|
|                                  | $\sigma_h = 67.3$ kPa              |  |
| TOTAL                            | 80.3                               |  |
| ARM 1                            | 85.3                               |  |
| ARM 2                            | 117.5                              |  |
| ARM 3                            | 120.9                              |  |

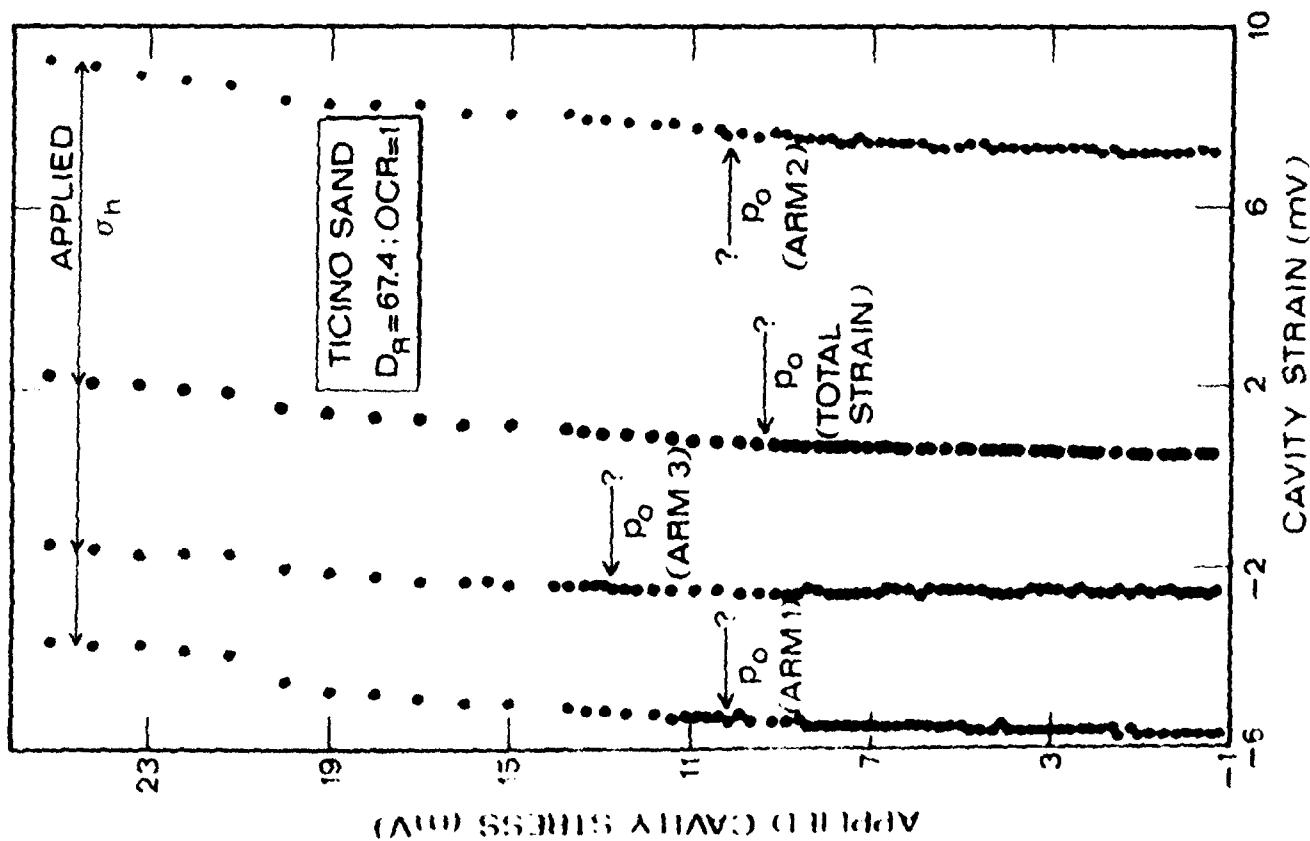
TOTAL STRAIN :  $1\text{mV} = 6.9 \cdot 10^{-3}$  mm  
 SINGLE ARM :  $1\text{mV} = 2.1 \cdot 10^{-2}$  mm  
 CAVITY STRESS :  $1\text{mV} = 10.02$  kPa

Fig. 2

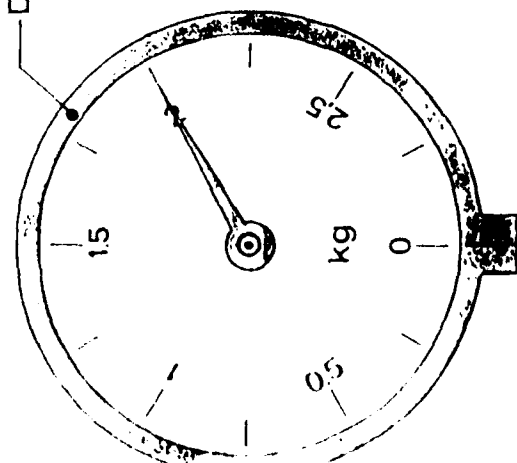
# SBPT IN CALIBRATION CHAMBER - LIFT-OFF PRESSURE STRAINS ARMS WITH A PRONOUNCED MECHANICAL COMPLIANCE

| STRAIN OF | "LIFT-OFF" $p_o$ (kPa) |       | APPLIED LATERAL<br>BOUNDARY STRESS<br>$\sigma_h = 242 \text{ kPa}$ |
|-----------|------------------------|-------|--|
|           | TOTAL                  | ARM 1 |  |
| ARM 1     | 91.4                   | 100.2 |  |
| ARM 2     | 100.2                  | 100.2 |  |
| ARM 3     | 124.7                  |       |  |

TOTAL STRAIN :  $1 \text{ mV} = 6.9 \cdot 10^{-3} \text{ mm}$   
 ARM 1 :  $1 \text{ mV} = 2.1 \cdot 10^{-2} \text{ mm}$   
 CAVITY STRESS :  $1 \text{ mV} = 10.02 \text{ kPa}$



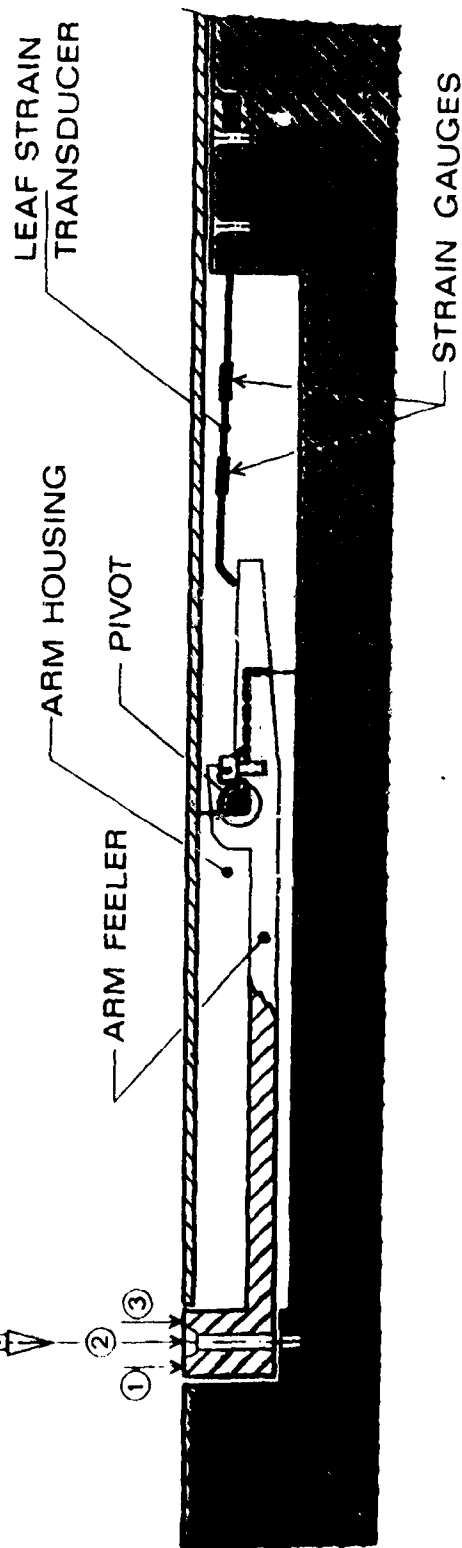
## DYNAMOMETER



ZERO READING SHIFT IN mV

| STRAIN ARM | POINT 1            |       | POINT 2 |       | POINT 3 |      |
|------------|--------------------|-------|---------|-------|---------|------|
|            | APPLIED FORCE IN N |       |         |       |         |      |
|            | 5                  | 30    | 5       | 30    | 5       | 30   |
| 1          | -3.5               | -4.0  | -4.8    | -7.1  | -5.1    | -7.5 |
| 2          | +9.4               | +10.8 | +11.4   | +11.7 | +10.6   | +9.5 |
| 3          | -3.1               | -0.8  | -2.7    | -1.3  | -2.9    | -2.5 |

NOTE: PRECISION REQUESTED FOR A RELIABLE  
ESTIMATE OF LIFT-OFF PRESSURE  
 $p_0 \approx 1 \text{ mV}$



# CHECK OF STRAIN ARMS FLEXIBILITY UNDER INCLINED EXTERNAL STRESS

Fig. 5

ZERO READING SHIFT IN mV  
UNDER APPLIED LOAD OF 10N

| ARM<br>N. | <del>10N</del> 30° | <del>10N</del> 30° |
|-----------|--------------------|--------------------|
| 1         | - 6.0              | - 4.8              |
| 2         | - 12.0             | - 10.8             |
| 3         | - 3.2              | - 2.0              |

NOTE: PRECISION REQUESTED FOR A RELIABLE  
ESTIMATE OF LIFT-OFF PRESSURE  $p_0 \approx 1 \text{ mV}$

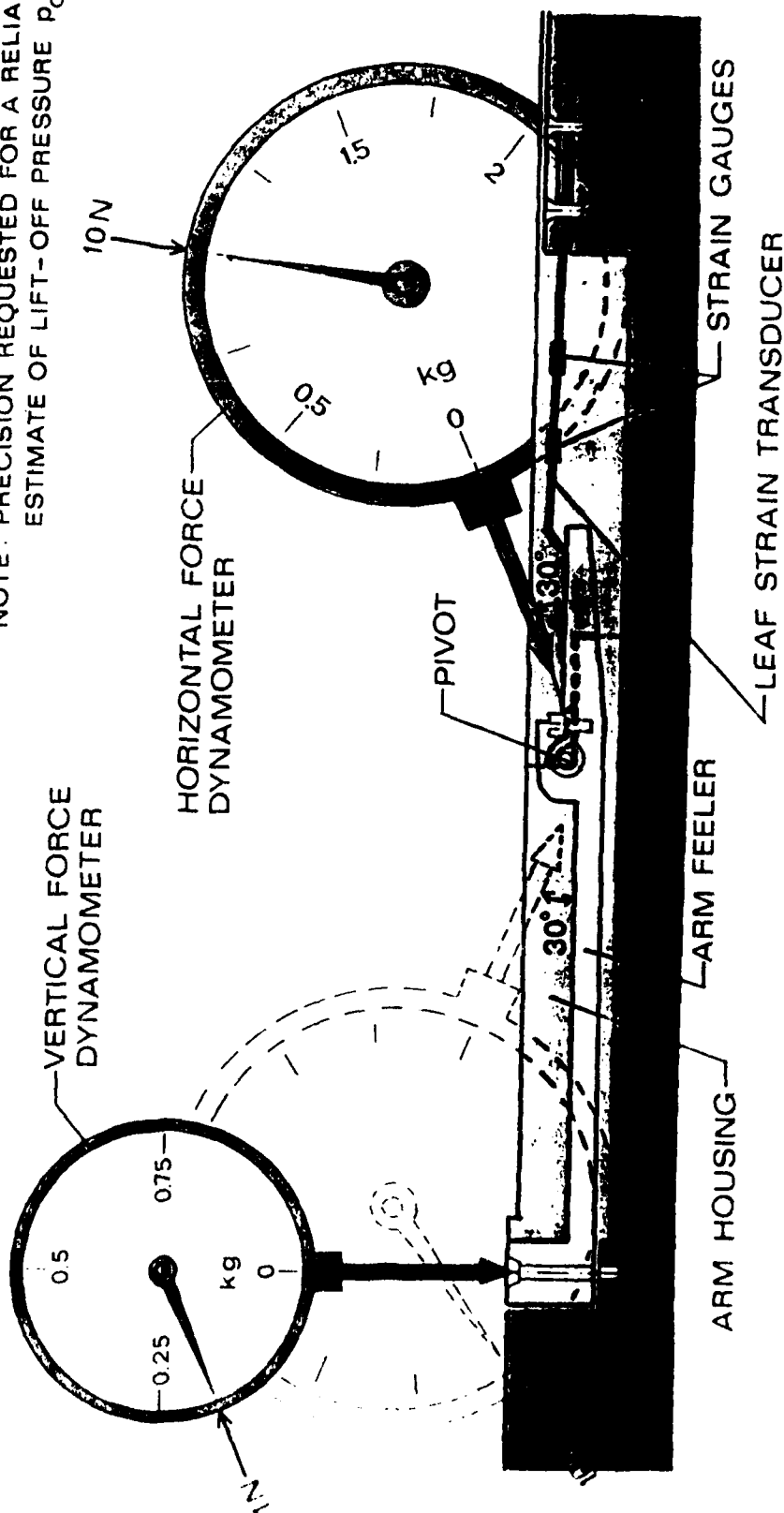
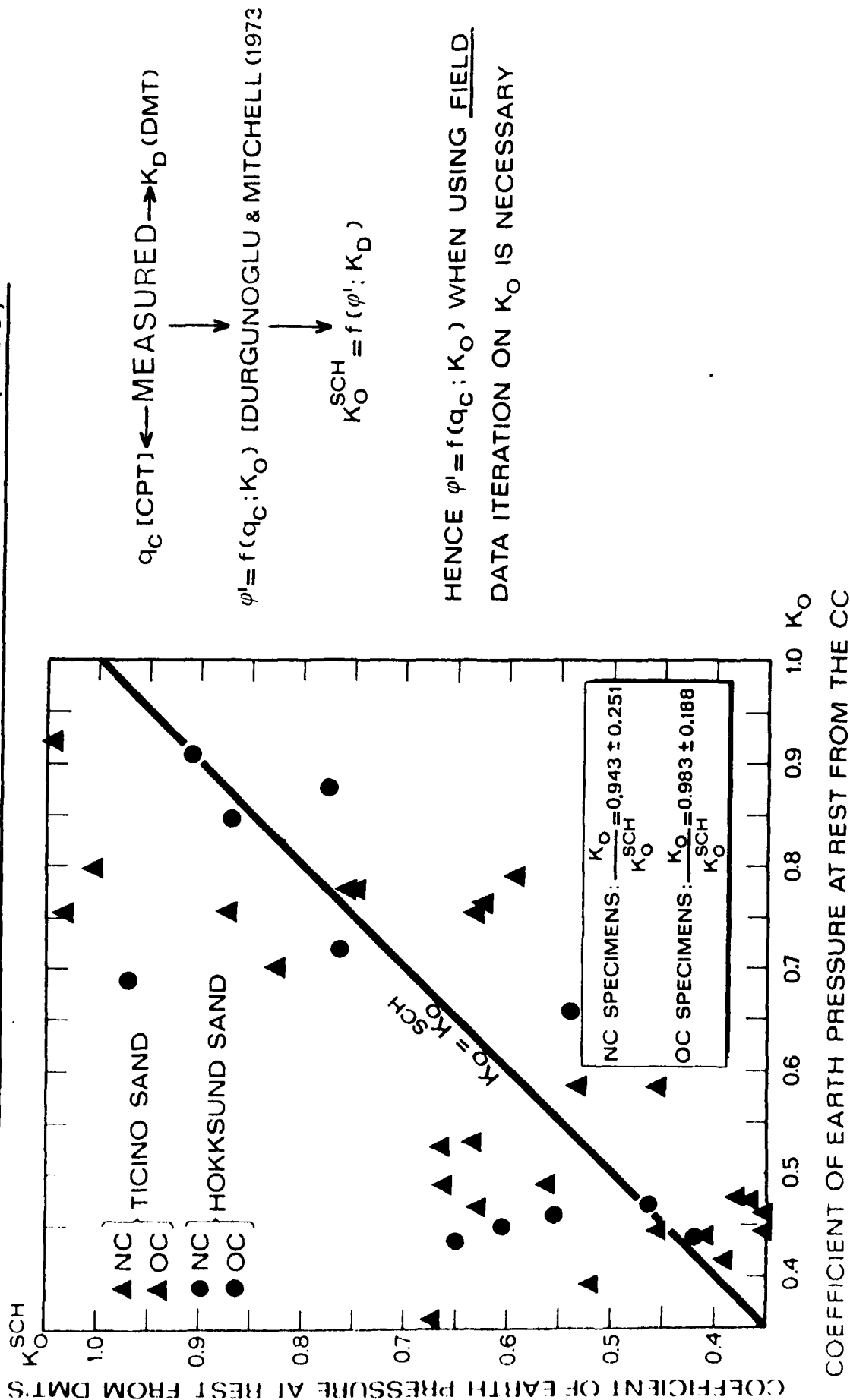


Fig. 6

# $K_0$ FROM THE CALIBRATION CHAMBER COMPARED TO THOSE FROM DMT'S

## OBTAINED ACCORDING TO SCHMERTMANN (1983)



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